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EXAMINATIONS FOR THE DRAINAGE OF LANDS

MADE BY THE

U.S.-DEPARTMENT OF THE INTERIOR.

January 7, 1908.—Referred to the Committee on Public Lands and ordered to be printed, with maps, etc.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

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From the
U. S. Government.

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EXAMINATIONS FOR DRAINAGE OF LANDS.

LETTER

FROM

THE SECRETARY OF THE INTERIOR,

TRANSMITTING

A REPORT UPON THE EXAMINATIONS FOR THE DRAINAGE OF LANDS, MADE BY THE DEPARTMENT.

JANUARY 7, 1908.—Referred to the Committee on Public Lands and ordered to be printed, with maps, etc.

Secretary's Office,
Department of the Interior,
Washington, D. C., January 4, 1908.

Sir: The following report upon the examinations for the drainage of lands, made by this Department, together with topographic maps and other data, is transmitted to the Senate in accordance with its request of December 11.

Very respectfully,

James Rudolph Garfield,
Secretary.

The President of the Senate.

REPORT ON EXAMINATIONS FOR THE DRAINAGE OF LANDS.

GENERAL STATEMENT.

Examinations for the drainage of lands have for many years been conducted by the United States Geological Survey, a bureau of the Interior Department, in the prosecution of the investigations of the Survey authorized by Congressional enactment. The first Director of the Survey interpreted the act of Congress creating the Survey as requiring him "to begin a rigid scientific classification of the national domain * * * and to produce a series of land maps which should show all those features upon which intelligent agriculturists, miners, engineers, and timbermen might hereafter base their operations * * * ." The act passed by Congress on August 7, 1882, authorized the Director of the Geological Survey to continue the preparation of such a geologic map of the United States.

The accumulated results of the investigations carried on under this and succeeding acts have served as a basis for many lines of Government work. As a result of the topographic and hydrographic surveys, for example, it became possible to commence the work of irrigating the arid lands immediately after the passage of the reclamation act of 1902. If the participation of the Federal Government in the drainage of wet lands should be approved, the same character of preliminary information will be necessary, and the Geological Survey work is as applicable to one as to the other. The following pages contain a statement of the amount and scope of information now on hand as the product of the regular work of the Geological Survey and the application thereof to the specific problems of drainage.

More than a half century ago the Federal Government took official cognizance of the vast swamp areas of the United States, and Congress in 1850 passed the swamp-land act, whereby there have been patented to the various public-land States, up to June 30, 1906, 63,324,318 acres of "swamp land." Following this, in the early eighties, Director John W. Powell, of the Geological Survey, assigned to Prof. Nathaniel S. Shaler the geological study of the swamps of the Atlantic coast. The results of Professor Shaler's first investigations are contained in a report on the Seacoast Swamps of the United States, published in 1884–85, as part of the Sixth Annual Report of the United States Geological Survey. This comprised a reconnaissance and study of the marshes of New England, which, according to the report, amount to some 15,000 acres.

Then followed a general investigation by Professor Shaler of the entire swamp area of the United States east of the one hundredth meridian, the results of which were published in the Tenth Annual Report of the Geological Survey, 1888–89. In this report Professor Shaler, referring to the value of swamp lands, pointed out that they contain the dormant wealth of the nation. He called attention to the fact that in Great Britain and Ireland fully one-fifth of the most fertile agricultural lands has been reclaimed by drainage. During the time of the Saxon Kingdoms, England was, to a great extent, occupied by morasses, the sites of which are now indicated by the great and persistent fertility of the soil. The same statement is true with reference to a large portion of northern Europe and to the valley of the Po in Italy. Professor Shaler estimated that not far from one-twentieth of the land now tillable in Europe was inundated and unfit for agriculture in the eighth century—in the same unprofitable condition in which are American swamps to-day. Calculating the drainable area in the United States at a total of 100,000 square miles, he compared the aggregate value of the district, measured in terms of production, with the area afforded by the fertile lands in the States of Ohio, Indiana, and Illinois. This report also included a detailed geological investigation of the Dismal Swamp in Virginia and North Carolina. These results were admittedly of a reconnaissance nature. In presenting a table of the principal swamp areas by States, Professor Shaler stated that the object was rather to indicate the importance of these lands to agriculture than to afford precise statistics as to the areas in question, and that such statistics could be obtained only when topographic maps of the country were available and the extent of each important morass carefully computed. (See Pl. I.)

It is not the province of this report to enter into the question of the desirability or value of drainage, as this is in every case a matter of estimate and opinion, while land values, either reclaimed or unreclaimed, are seldom alike in two localities. It may be broadly stated, however, that aside from the reclaimed swamp land near cities, the value of which can not be computed, it is well known, as stated by Professor Shaler, that for farming purposes reclaimed swamps furnish by far a greater store of available plant food than any other class of land.

An important feature of Professor Shaler's work was his study of the origin of morasses, their division into types, and their methods of growth. Such information is of great practical importance in the investigation of wet lands, because it permits the classification of morasses according to their agricultural value when drained.

The Geological Survey investigations of morasses have not been confined to the work of Shaler; but since the beginning of the Survey's operations they have been an important feature of the topographic work whenever such lands occurred in the areas under survey.

The making of a geologic map of the United States is a public work and is maintained by appropriations made annually by Congress. One-third of the area has already been covered topographically, and maps representing the results of these surveys are being printed at the rate of one new sheet every three days. The area covered by new maps published last year is 32,448 square miles, this work costing about $327,405. The facts shown on these maps, together with the hydrographic and geologic investigations of the Survey, afford all the preliminary information required for determining the feasibility of drainage projects and for planning the broad features, such as the location of levees and ditches. The engineer who is provided with such maps may proceed with his work with all the facts in mind, and he will not be liable to overlook some feature or physical condition that may later work adversely to his project.

The drainage of lands is a matter of practical engineering. The preliminary requirements are in no wise different from those governing the irrigation of arid lands, the construction of inland waterways, the prevention of floods, the conservation of water, or any other important engineering development. Such problems all involve engineering and physical factors, the control of which may extend beyond the area immediately under consideration. Therefore any great project of wet-land drainage is far above the plane of mere local ditching for the purpose of draining a few farms. If such work is to be prosecuted intelligently and purposefully the actual construction must be preceded by topographic surveys, measurement of stream flow, consideration of necessary capacity of channels both natural and artificial and their permanence, investigation of geologic conditions, and study of all the related phenomena of a climatological nature. The actual development can be prosecuted only by a competent corps of engineers.

The Geological Survey, up to June 1, 1907, had completed the topographic mapping of 34 per cent of continental United States. This is equal to 1,025,065 square miles, distributed as indicated in Table 1 and on Plate II.

TABLE 1.—*Area mapped and wet-land area in the United States.*

State or Territory.	Area in square miles.			Estimated land area needing drainage.	Morasses mapped by U. S. Geological Survey.
	Total, including water surface.	Mapped to June 1, 1907.	Per cent mapped.		
				Acres.	*Acres.*
Alabama	51,998	18,283	35	1,120,000	9,600
Arizona	113,956	62,712	55	....	....
Arkansas	53,335	20,469	38	5,760,000	144,400
California	158,297	79,381	50	1,000,000	294,900
Colorado	103,948	37,766	36	....	....
Connecticut	4,965	4,965	100	37,700	37,700
Delaware	2,370	1,008	43	200,000	77,200
District of Columbia	70	70	100	....	....
Florida	58,666	1,821	3	18,560,000	107,500
Georgia	59,265	16,855	28	2,400,000	....
Idaho	84,313	15,196	18	....	....
Illinois	56,665	7,400	13	2,688,000	48,900
Indiana	36,354	2,458	7	800,000	1,600
Iowa	56,147	9,895	18	500,000	3,400
Kansas	82,158	64,159	78	160,000	....
Kentucky	40,598	14,515	36	224,000	....
Louisiana	48,506	7,923	17	9,600,000	2,868,800
Maine	33,040	6,805	20	2,560,000	50,200
Maryland	12,327	10,294	84	328,800	352,900
Massachusetts	8,266	8,266	100	148,000	147,900
Michigan	57,980	3,753	6	4,800,000	248,400
Minnesota	84,682	2,876	3	3,840,000	128,600
Mississippi	46,865	906	2	6,173,000	72,600
Missouri	69,420	34,017	49	1,920,000	16,300
Montana	146,572	47,189	32	....	3,300
Nebraska	77,520	25,974	34	256,000	1,100
Nevada	110,690	40,482	36	....	3,600
New Hampshire	9,341	3.160	33	384,000	10,500
New Jersey	8,224	7,821	95	592,300	592,300
New Mexico	122,634	28,735	23	....	....
New York	49,204	38,209	80	1,600,000	458,300
North Carolina	52,426	17,074	33	2,400,000	428,100
North Dakota	70,837	8,775	12	226,000	16,100
Ohio	41,040	19,997	49	800,000	36,000
Oklahoma [a]	70,057	36,495	52	....	5,900
Oregon	96,699	16,280	17	....	238,400
Pennsylvania	45,126	19,608	43	192,000	49,500
Rhode Island	1,248	1,248	100	17,900	17,900
South Carolina	30,989	5,496	17	1,760,000	....
South Dakota	77,615	17,956	23	226,000	40,300
Tennessee	42,022	20,103	48	800,000	....
Texas	265,896	65,845	25	2,240,000	....
Utah	84,990	63,320	75	....	....
Vermont	9,564	3,537	38	256,000	27,200
Virginia	42,627	29,829	70	1,024,000	231,800
Washington	69,127	18,228	26	....	42,000
West Virginia	24,170	24,120	99	....	....
Wisconsin	56,066	11,197	20	2,880,000	647,200
Wyoming	97,914	22,594	23	....	49,400
Total	3,026,789	1,025,065	34	78,473,700	7,509,800

[a] Including Indian Territory.

The results are comprised in 1,637 topographic sheets which have been published by the Geological Survey, and of these, 402 show swamp areas scattered throughout all the principal sections of the United States. All of these indicate graphically the locations and boundaries of the swamps and their relation to the natural drainage channels, as well as the configuration of the surrounding country. The area of land which is subject to overflow, but which can not be considered perennial swamp, is not included in this report because it must be determined by a combination of climatological and flood-flow data—information at present unavailable. A study of these maps indicates that undoubted success would attend the effort to drain wet lands in a very large number of areas in widely separated parts of the country.

The primary purpose of the topographic work of the Geological Survey is to secure a base for the geologic map of the United States described in a preceding paragraph. No suitable geologic map could be made without topographic surveys. Therefore the specific localities chosen for topographic mapping have naturally been those of greatest geologic or mineral importance. Such areas must of necessity have taken precedence over those in which the geologic features are subordinate.

Of course, in work of this kind the determination of the areas to be surveyed has been to a certain extent influenced by related Federal demands whenever the ultimate progress of the geologic map would not be inhibited thereby. While preserving the original purposes, it has been possible to facilitate other lines of Federal investigation. For example, before the organization of the Reclamation Service the Geological Survey had made large numbers of reconnaissance surveys of arid lands, which furnished a base for national reclamation of these lands.

Realizing the preparedness of the Survey and the fitness of its trained men for work of this character, Congress has seen fit in past years to delegate to it certain special mapping, for which special appropriations have been made. The Indian Territory and certain boundary surveys are examples of work of this character. Also, the mapping of national forests for the Forest Service, Department of Agriculture, is carried on by the Geological Survey topographers, under special appropriation, the former bureau being actuated by a desire to secure the best results for the least expenditure of money.

Thus, the Geological Survey has collected the topographic information indicated in Table 1 and Plate II, and for the ascertainment of the necessary facts concerning lands needing drainage it is merely necessary for Congress to authorize the extension of the scope of current work to cover this specific purpose, as has heretofore been done to meet other needs.

USES OF TOPOGRAPHIC MAPS.

These maps have a wide range of usefulness, both to the Government and to the public, being, in fact, the mother maps of the country. They have this value because the plans adopted for their survey are the mature result of years of thought and experience. The field work is so coordinated that the final result will be one great harmonious map of the country, systematically and scientifically constructed, and not scattered or haphazard plats independent of one another and of various degrees of accuracy.

The State Department makes use of them in connection with questions relating to the international boundaries. Wherever special boundary surveys have been made the results are incorporated in these maps.

The War Department uses the maps in many ways. The triangulation and leveling are of special value to the Engineer Corps as a basis for detailed river studies. The military information division adds to the regular topographic maps such special field notes as are of service in maneuvers, such as location of wood, water, etc. One of the army officers engaged on this work states that he has been able in this way to record in one month the data which otherwise would have taken him two years to collect and map.

The Post-Office Department finds these maps exceedingly useful in defining rural routes and the lengths thereof, and by mere consultation of the maps is frequently able to regulate the establishment of new offices without field inspection.

The Treasury Department, through the Coast and Geodetic Survey, in 1903, made an adjustment of the great national net of precise levels, consisting of 19,753 linear miles run by various organizations. Of the Geological Survey leveling, 1,740 linear miles, or all that was so situated as to be available at that time, was utilized in this adjustment. The Geological Survey has run altogether 6,500 linear miles of the highest class of levels, which will ultimately be absorbed in this great net. In addition, many thousands of miles of ordinary quality have been run.

The Department of Agriculture has many uses for the sheets, plotting on them the soil areas when published maps are available, and using them in statistical work of various kinds. The Forest Service invariably uses these maps as a base on which to show timber stand and to plan operations.

In fact, there is scarcely a single branch of the Government service in which the topographic maps and records of the Geological Survey are not commonly required, and to which the published sheets are not furnished for official use. Efforts are being made by the Geological Survey to secure cooperation with all of these bureaus, with a view to increasing the usefulness of the maps and to avoiding any duplication of work.

The public uses of the maps are so numerous as to preclude any classification.

FEATURES SHOWN ON TOPOGRAPHIC MAPS.

On the topographic maps made by the United States Geological Survey, blue denotes water, brown denotes relief, and black denotes roads, bridges, houses, and other works of man. If these facts are kept in mind, the maps will assist in telling their own story.

Examination of one of the typical maps will show that the color blue appears in many shapes and outlines. When it appears in crooked bands, some wide and some narrow, it is obvious that rivers and streams are indicated. When the blue appears in spots of different shapes and sizes lakes or ponds are represented. On some of the maps other blue spots will appear, sometimes covering considerable space along the borders of the streams. These spots are made up of tufted lines that appear like bunches of grass and will readily be recognized as representing swamps and morasses. Some of these are salt marshes, represented by tufts on parallel lines, while to indicate fresh-water swamps the parallel lines are broken.

As above stated, brown denotes relief. By relief is meant the variation in height and shape of the land surfaces. The hills and mountains and the lowlands and valleys are shown in this way. The brown lines, known as contour lines, represent positions that are at certain levels above the sea, and should one go upon the country shown by one of these maps and take a course along the path defined by one of these lines he would always be at the same elevation above sea level. At points readily identified the elevation is shown by figures to the nearest foot. Wherever these lines are closely set, that is, where there are only small or narrow spaces between them, it is obvious that the slopes are steep, but where they are far apart the slopes are gentle or indeed practically flat.

Everything on the map in black denotes development or division by mankind. A single heavy, broken black line denotes a political boundary. A double line denotes roads. Double broken lines denote private roads, wood roads, etc. In a similar conventional manner are shown railroads, canals, walls, bridges, ferries, fords, dams, locks, etc., while signs are adopted to denote bench marks, cemeteries, churches, schoolhouses, oil wells, mines, shafts, light-ships, lighthouses, life-saving stations, etc. All of these signs are illustrated and named on the back of each sheet.

It is possible to trace on such a map the area of a morass, the amount of land surface tributary to each stream, and the relative elevations of all topographic features. In other words, the map enables one to study the general situation in the only possible way to reach a thorough knowledge of the facts relating to any proposed improvement.

COST OF TOPOGRAPHIC MAPS.

The cost of these maps varies widely, according to the character of the country and the necessity for detailed surveys. Open, sparsely settled regions demand less detailed surveys than crowded, busy manufacturing and agricultural districts.

The cost of both field and office work during the year 1906–7 was 2.3 cents per acre for the Atlantic coastal plain, 3.5 cents per acre for the Appalachian region, and 2 cents per acre for the Mississippi Valley. The maps of these areas are all being published on a scale of about 1 inch to 1 mile, with contour intervals of 10 to 20 feet. The cost of surveys for special maps of various regions, especially in the case of detailed work in mountain country, far exceeds the above figures, but large-scale and accurate surveys, especially adapted for irrigation and drainage purposes, have not cost the Geological Survey more than 5 cents per acre, while in simple cases the cost has been as low as 1.6 cents per acre.

TYPICAL MAPS.

Several topographic maps, showing incidental swamp surveys, are here described, and the typical drainage problems presented therein are briefly discussed, in order to exemplify the practical application of these maps in the study of such problems.

CALIFORNIA MAPS.

In the Sacramento Valley and along its tributary valleys there are about 1,000,000 acres of the richest of lands that are subject to overflow. Some of this section has already been reclaimed, and as raw land it is valued at several hundred dollars per acre. The usual plan in reclaiming these lands is first to build a protecting levee and then to pump out the water inclosed. This is shown in the Sacramento Valley sheet "M" (Pl. III). In some of these lands, following drainage, irrigation is practiced by siphoning water back from the river.

Cooperative topographic surveys have been made by the Geological Survey and the State of California with special reference to drainage reclamation in this valley. The mapping of this area has been done on scales specially suited to meet fully the needs of drainage operations. With contour intervals of 5 feet, the field and office work has cost an average of 4 cents per acre. More detailed engineering data, not shown on the published map, are also on file in the office of the Survey and are available for any future requirements that may be made. In connection with these topographic surveys the level lines along the valley of Sacramento River and the permanent bench marks established at regular intervals will be of great importance in connection with all future construction of public works in the valley.

CLARKSDALE MAP.

In the upper Yazoo Delta, Mississippi, the Clarksdale quadrangle (Pl. IV), covering an area of 206,720 acres of swamp and overflowed land, was partially surveyed in 1907, in cooperation with the State of Mississippi, at a cost of 1.8 cents per acre.

The lands throughout this section have been formed by graded deposits of clay and sand, dropped by the receding floods of Mississippi River through countless ages, and are stated by the Department of Agriculture to be more fertile than even the rich loams of the Central States.

The peculiar physiography of this section is interesting both to the geologist and to the agriculturist. The gradual burial by silt of the ancient eroded delta furnishes a lesson to the former and a problem to the latter.

The map shows each bayou and slough, indicating their depth and their relation to the surface drainage in an unusually detailed manner, bringing out with special force the recent deeply cut channel of Sunflower River, resulting from a crevasse in the parent stream. It shows conclusively that every acre of the flat alluvial surface can be rescued from mosquitoes and consequent malaria and drained into this channel, which is separated at its old head from the Mississippi. It now has banks 44 feet high at Clarksdale and is capable of carrying the drainage from an immense territory.

MINNESOTA MAPS.

In the drainage survey of the Chippewa ceded lands of northern Minnesota (Pl. V) made during the past two years by the Geological Survey there is presented a class of work somewhat different from that of previous surveys. Minnesota has more than 6,000 square miles of wet lands and its legislature has made various appropriations for drainage work. The fact that comparatively few regular topographic maps of the United States Geological Survey are available for this State has made reconnaissance surveys absolutely necessary in all portions of the State where swamp-land drainage is being considered. By acts of Congress carrying an aggregate appropriation of $25,000 the Secretary of the Interior was directed to make drainage surveys and construction plans of the swamp lands comprised in the ceded Chippewa lands, embracing about 3,800 square miles in northern Minnesota. This is the only extensive tract of swamp land remaining in public ownership.

Proceeding under this authorization, the Geological Survey has made detailed drainage surveys of 402,500 acres and has drawn plans for their reclamation. The cost of this survey was 1.6 cents per acre. It has also made, during the field season just closed, a detailed survey of about 1,280,000 additional acres, and is now working on office plans for the reclamation of this area. At least 750,000 acres of this ceded Chippewa land yet remain to be surveyed to fully comply with the directions of Congress.

This drainage survey presents a concrete example of the availability of the Geological Survey for any special class of surveying which may be delegated to it by Congress. As the legislation provided that this survey should be solely for drainage purposes, the usual methods of topographic mapping were modified to conform to this specific object. This modification, however, was mainly one of elimination of certain features of the regular topographic surveys of the Geological Survey. A full description of the survey, with reclamation plans of the first year's work under this special appropriation, is found in House Document No. 607, Fifty-ninth Congress, second session. It may be remarked that, had regular topographic mapping been extended over northern Minnesota, this special drainage survey would not have been necessary and much of the expense of preliminary surveys over other areas of the State could have been saved. However, since a drainage survey was what was desired by Congress, the existence of the topographic branch of the Geological Survey, with its thorough organization for field work and its available corps of trained topographers, has made it possible to prosecute this survey with the greatest economy as to cost and time, and with the most authoritative and comprehensive results.

MADISON MAP.

Madison, Wis., is located on a narrow strip of land and swamp separating Lakes Mendota and Monona. The topography, as shown by the Geological Survey map, is typical of the glacial-drift country, with its low, irregular hills, interspersed with swamps which are all at a nearly uniform elevation. These swamps in their present condition are a serious menace to the health and the comfort of the inhabitants of Madison. Their drainage, as shown by the topographic map of this quadrangle, presents a difficult problem from the fact that there is insufficient slope and because of the serious damage that would result to the business interests of the city should the lakes be lowered. The drainage of parts of the Madison swamps has been proposed and attempted, but without a topographic survey. These attempts have been abortive. Had the information shown by this map been in hand, no engineer would have recommended the prosecution of such work, but rather would have fallen back on the plan of diking the swamps and pumping out the surplus water—a remedy often adopted under similar conditions. In this connection it may be stated generally that drainage may be accomplished not only by the ordinary method of ditching, but under certain conditions the results may be attained by levees, dikes, sluices, or pumping, or by a combination of these.

SYRACUSE MAP.

This map (Pl. VI) shows another example of the value of topography in readily determining whether drainage projects are feasible. Lying between Oneida Lake, which is shown by the map to have an elevation of 370 feet, and Onondaga Lake, at 364 feet, are two tracts known as the Cicero Swamps. One of these swamps is shown to have an elevation of 395 feet and the other of only 365 feet. The lower one, with its very slight elevation above the drainage channels shown, would appear clearly to be impracticable of drainage by ditching, while the higher one, which approaches within 2 miles of Lake Oneida, could readily be ditched and drained.

STATEN ISLAND MAP.

On the Staten Island sheet, covering part of New Jersey and extending from the lower end of Staten Island to a point well above the Battery, is shown an entirely different type of wet land, viz, the salt marshes along Arthur Kill and Hackensack River. A large area has already been reclaimed, as shown by the map, while a study of this map and that of the Paterson quadrangle on the north indicates that thousands of additional acres now lying idle can be readily drained. The maps show plainly the accessibility of the land, the drainage which must be handled, and the general locations for the necessary dikes.

WILLIAMSTON MAP.

Throughout eastern North Carolina occur immense swamp areas, where the partially reclaimed lands under cultivation vie in fertility with the richest bottom lands of the Mississippi Valley. Extensive swamps are found along all the rivers in the seacoast section, such as are shown on the Williamston sheet (Pl. VII). This map portrays Roanoke River flowing with but a slight fall and meandering through its flood plain, which here has a width of about 4 miles. The river is rich in silt and has fertilized this valley to a great depth in an unknown number of years, so that wonderful conditions of plant growth are possible. A study of this map in the hands of an engineer, taken in connection with the gagings of the river made by the Geological Survey hydrographers, makes clear the feasibility of straightening the stream's tortuous course, constructing dikes to confine the flow, and reestablishing the regimen of the tributary streams. Without such comprehensive and detailed topographic and hydrographic data no intelligent plans for drainage could even be formulated.

PANASOFFKEE MAP.

The necessity for extending surveys and the impossibility of accomplishing drainage by individual effort is nowhere more evident than in Florida and Louisiana. The area of wet lands in these States is so vast and the natural drainage channels, such as they are, so complicated that it is easier there than in most other places to make expensive mistakes.

For example, the map of the Panasoffkee quadrangle in Florida, about one-half of which is swamp, covers an area of about 240 square miles and is yet insufficient to give the key to the drainage; add to this the map of the area to the west, the Tsala Apopka, with another 240 square miles, and still the information is insufficient; add the Dunnellon sheet, showing the area north of the last, and for the proper understanding of this region we still need maps of areas to the south which are yet to be surveyed; so that in order to plan for the drainage of this one swamp along Withlacoochee River a survey of not less than 1,000 square miles is necessary. But when the map work shall have been carried far enough to give the engineer a thorough understanding of the lay of the land there will be no excuse for building expensive failures which are not only costly in themselves, but which deter others from taking up legitimate projects.

HYDROGRAPHIC INVESTIGATIONS.

No intelligent wet-land drainage can be accomplished with entire success unless the work is planned and executed with due regard for all necessities imposed by conditions affecting the flow of streams and the run-off from drainage areas, not only in the immediate localities in which the actual drainage work is to be performed, but throughout the tributary basins. Therefore the study of these matters ranks with the making of topographic surveys as a necessary preliminary to drainage construction. It should be remembered that the drainage of swamp lands involves merely the providing of means that will serve to accelerate the rate of run-off. In other words, the character of a certain area is changed from one that slowly yields up its stored water to one which gives up its water immediately. Take, for example, any river basin. It is well known that there are certain parts that dry out quickly after heavy precipitation, while other parts, commonly termed "swamps" or "morasses," give up their water slowly. The whole purpose of drainage is to put these wet lands in a condition in which they will yield up their stored water from precipitation as readily as, or in some cases more readily than, the well-drained parts of the basin.

Now each part of the basin has a certain amount of water, derived from precipitation, of which it has to dispose. The capacity of the river channels leading from all parts has been adjusted by nature so that they will readily carry off this water. Channels leading from quick-spilling surfaces are usually scoured and eroded until they can carry, without overflowing, all the water derived from such areas except in case of unusual flood. Conversely, channels from flat and swampy land are adjusted in the same way to accommodate the flow from such land. Now when such lands are drained these channels are artificially opened up or new ones are constructed, so that they will carry the water in greater quantity and within a shorter period. It must then be important to determine what size or capacity of channel will be sufficient to drain the water from such an area. If a ditch be too small, it will not perform satisfactory service. If it be too large, the parties engaged in the work of drainage will have expended more money than is necessary. When one considers the enormous areas contemplated in national drainage projects, it is readily seen that the Government might needlessly expend a huge sum of money by making ditches larger than is necessary. Therefore this matter must be studied at the outset, and the amounts of water that may be expected to flow from such areas should be determined, so that the ditch capacities may be made to fit such conditions.

It is obvious that this water drained from wet or swamp lands must be discharged into effluent rivers. Therefore river channels themselves must be adjusted so that they will carry a larger amount of water during flood seasons than they were previously called upon to carry. This is a most vital point. It must be remembered that by draining lands we are increasing the liability of the occurrence of floods in the rivers below. Any work that has the effect of increasing the rate of run-off from any portion of a basin must also help to fill the channel draining from that portion. It is very probable that unless this matter is handled with discretion there would be cases in which the values derived from the drainage of swamp lands would be more than offset by the damage caused in other parts of the basin, due to the occurrence of floods. The effect of this would be to create values in one place at the expense of values in another, but as the purpose of drainage is to increase wealth such a result would be entirely subversive.

The adjustment of channel capacities described in preceding paragraphs is specially important in those wet lands that border the rivers into which it is proposed to discharge the drained water. Such lands are usually overflowed by the rivers in flood season and practically become part of the river channel. It is therefore necessary to protect these lands by the erection of levees, and the location and height of the levees must be determined by the amount of water that the channel must carry. In order to determine this, hydrographic investigations, relating not only to the immediate area but to the entire drainage basin, must be made. It is well known that if a levee is set too far inland from the river banks, large areas of extremely valuable land may remain outside of the levee exposed to floods, not susceptible of drainage, and therefore lost. On the other hand, if the levees are placed too near the banks, the channel capacity of the river may not be sufficient, and the levees will be overtopped, with the usual great destruction of property. This, therefore, is another instance in which is demonstrated the necessity for preliminary hydrographic investigations.

For the period of fifteen years the Geological Survey has been carrying on such investigations under appropriations made from year to year by Congress embodied in the sundry civil bill, as follows:

> For gauging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells and the preparation of reports upon the best methods of utilizing the water resources.

The work above referred to has been continued under varying appropriations from year to year, and although it is not yet complete the results are of prime value in connection with all questions of water-supply development. Such of the work as has been done is directly applicable to the problem of land drainage. As in the case of the topographic surveys above described, special attention to land-drainage work in the future will require merely the allotment of specific sums from the appropriation to investigations of this character. Large allotments have, for example, been made from year to year in the interest of irrigation by reason of the activity of the United States in the prosecution of this work. A similar allotment of funds could with propriety be made to further enhance the interests of drainage, should Congress so direct.

The extent of the Survey's hydrographic work is shown in Plate II.

WORK OF THE RECLAMATION SERVICE.

The United States Reclamation Service in connection with the reclamation of lands in the arid region is confronted with many problems involving the drainage and relief of agricultural lands from excess of water. In any extensive region where irrigation is introduced, drainage is a necessary adjunct; otherwise, lands become water-logged and the water evaporating from the surface brings up alkali from the depths and eventually renders the land unfit for cultivation. Vast areas of land have had their fertility thus destroyed in Asia and Africa, in several of the Western States, and in other regions. Consequently, wherever drainage is not provided by nature, either by a considerable slope of the surface or by a subsoil of gravel or coarse sand, drainage must be provided artificially in order to prevent the destruction of fertility.

A typical region where drainage is a necessary accompaniment of irrigation is the Lower Carson Valley in the Truckee-Carson project, Nevada. The irrigation ditches follow the high lands and are constructed on the surface of the ground. The drainage ditches follow the lower portions and are usually entirely below the surface. Similar problems are encountered on other reclamation projects, such as the Bellefourche, S. Dak.; Yakima, Wash.; Minidoka, Idaho; Carlsbad, N. Mex., and others, where the irrigated lands must be promptly relieved of surplus water through drainage ditches.

In other regions the existence of surface water presents radically different problems. The Yuma project on the lower Colorado River will irrigate valley lands which in normal years are submerged by the annual overflow of the Colorado River, occurring in May, June, and July. To make this land habitable and productive it is necessary, first, to protect it from the overflow of the river; second, to supply it with water for irrigation; and third, to relieve it of the surplus waters which would be injurious if allowed to collect and evaporate. For protection from the floods of the river, levees are built on each side of the river of a sufficient height to prevent the normal overflow. Water is supplied through irrigation ditches to irrigate the land and the surplus is carried away by systems of drainage ditches constructed in the lower ground of the valley.

During the season of flood flow the water level in the river is higher than the surface of the valleys under cultivation. During this short period the drainage water will be collected and pumped over the levees into the river. The plan is to do this by means of water power secured from drops in the canal. The map of the Yuma project (Pl. XII, Fifth Annual Report of Reclamation Service) shows the location of the levees, irrigation canals, and the main drainage canals of the valley.

Such problems as that of the Colorado Valley are susceptible of a complete or partial solution by another method. If funds were available it would probably be found more effective and desirable to control the entire volume of Colorado River in storage reservoirs, involving very large expenditures, and allow the surface waters to flow to the sea in moderate volumes that would not overflow the banks of the river, most of the water being used for irrigation. This would entirely eliminate the necessity of levees and drainage pumps and, to a large extent, the drainage ditches. The storage system will be

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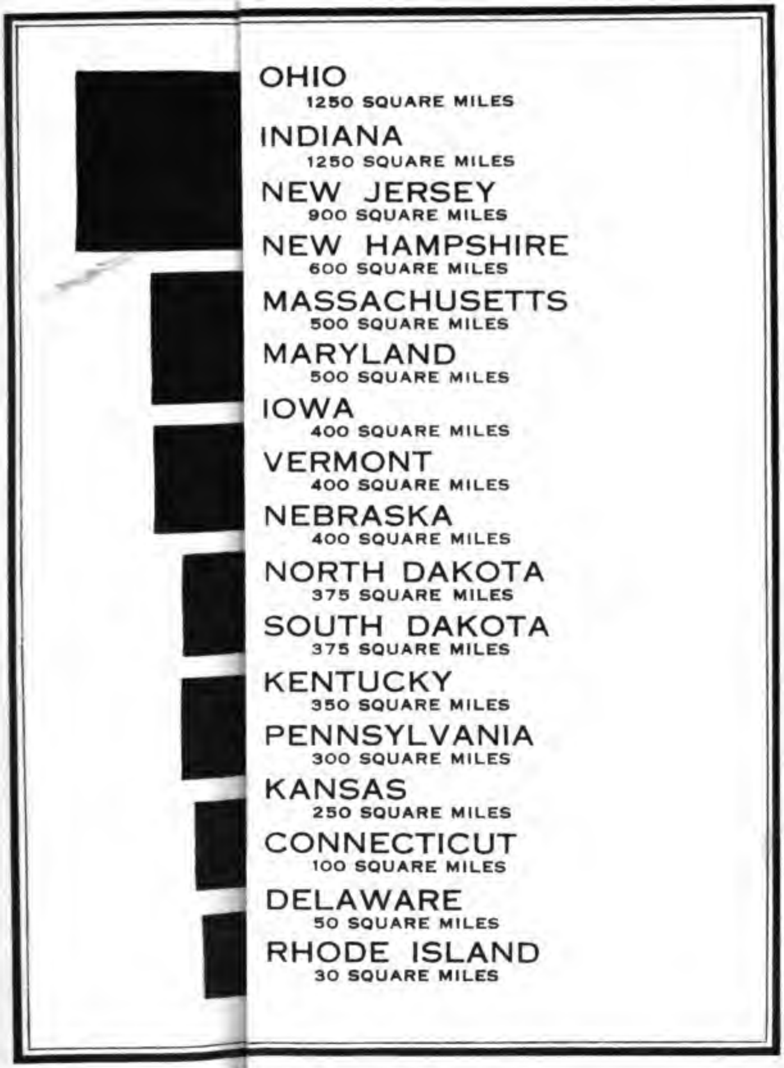

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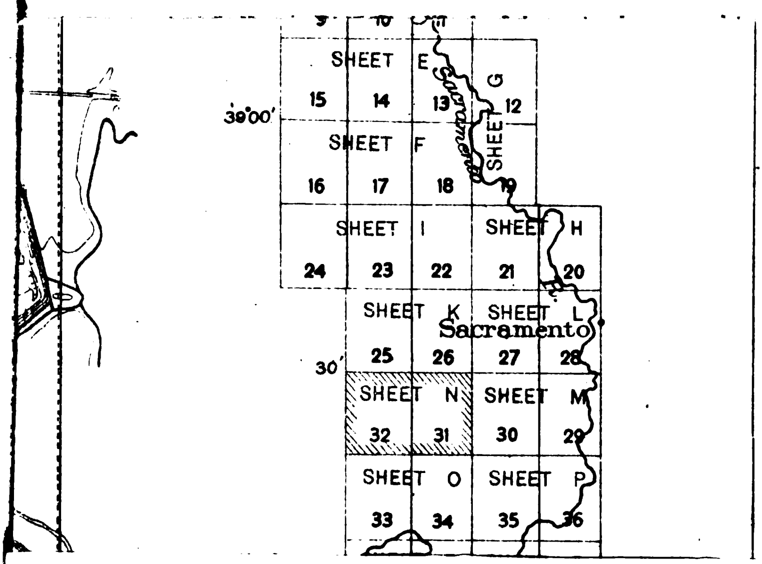
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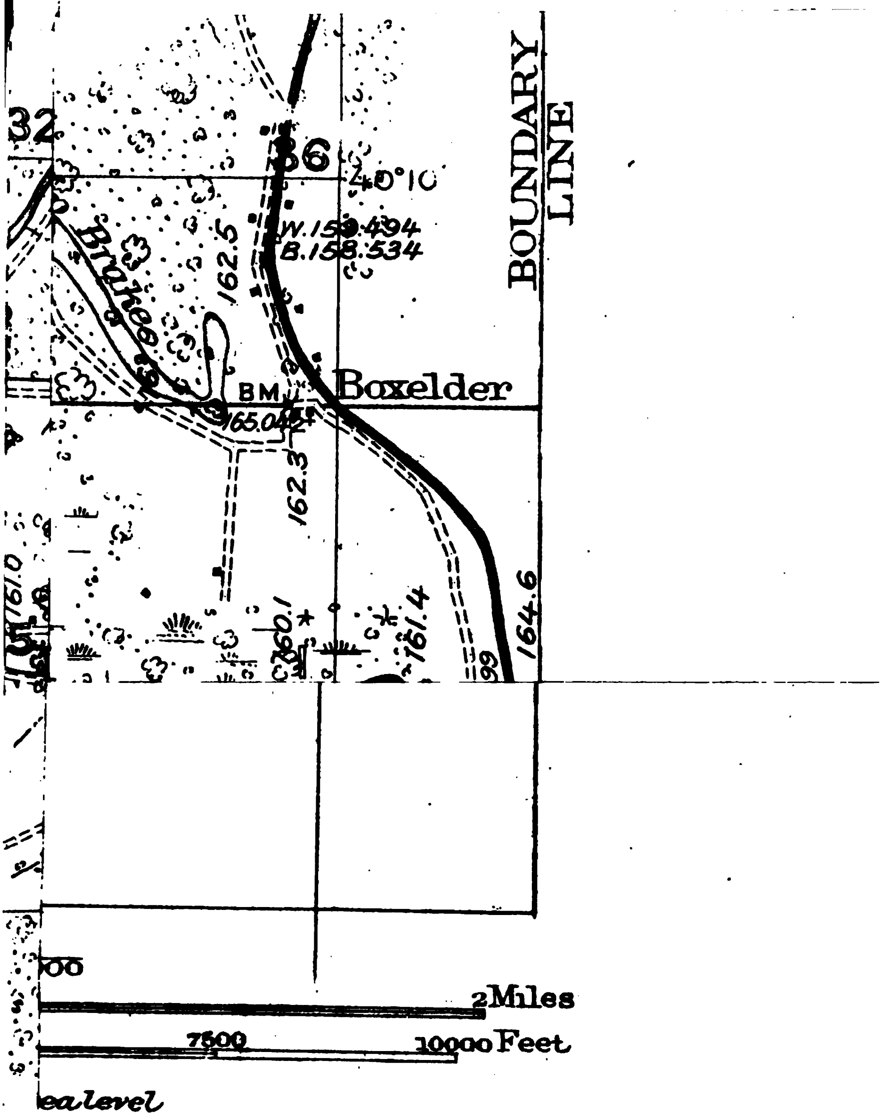

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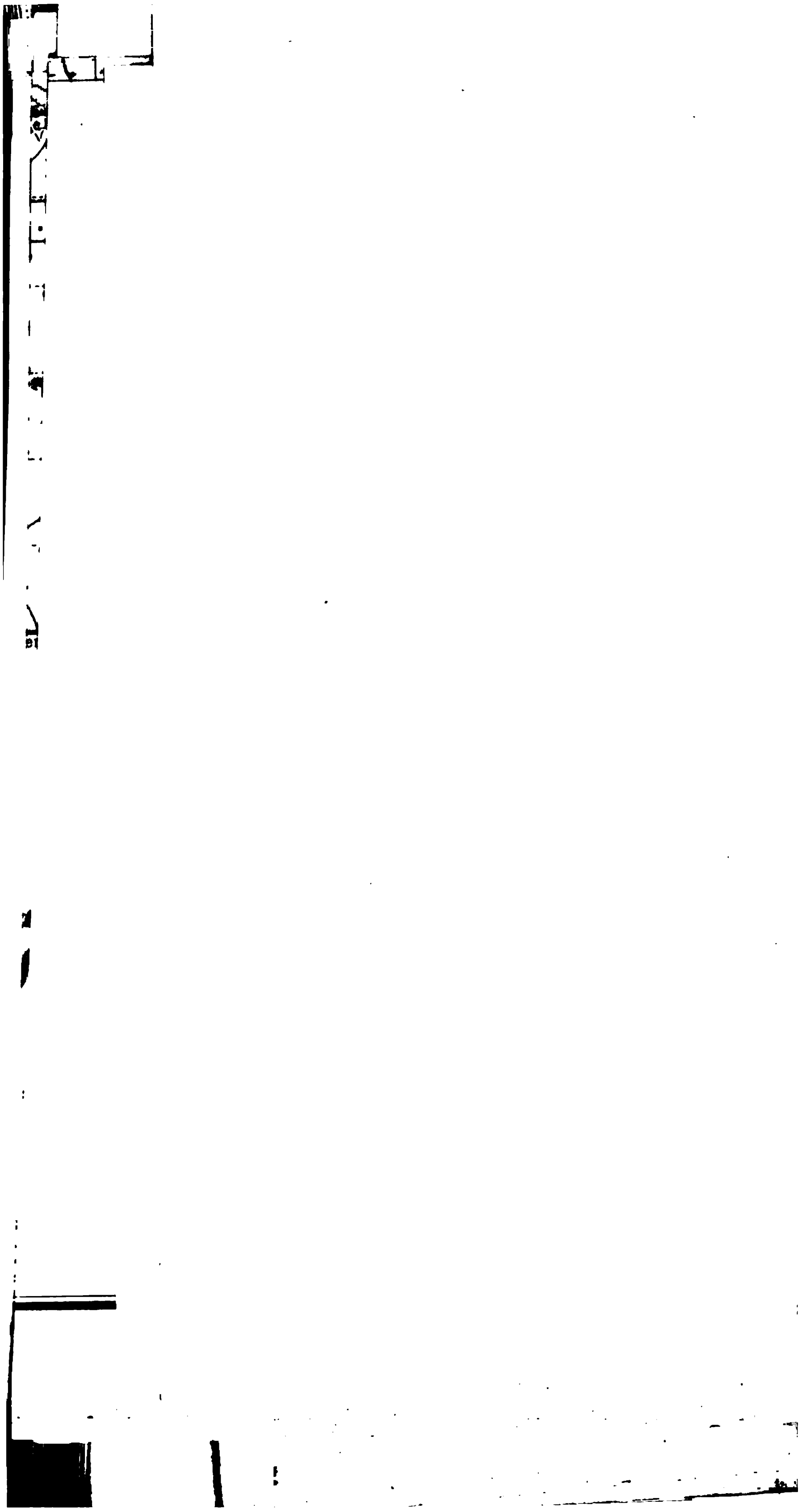

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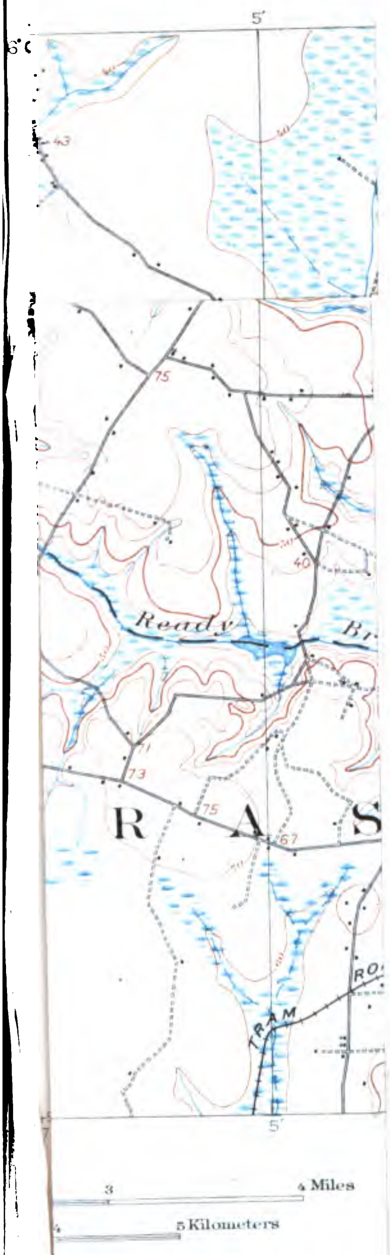

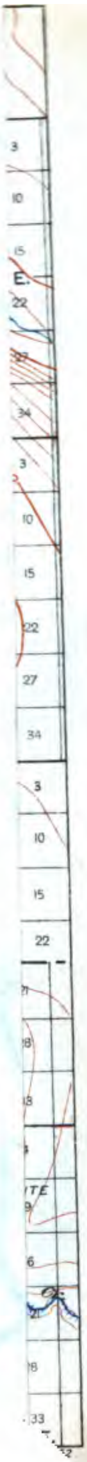

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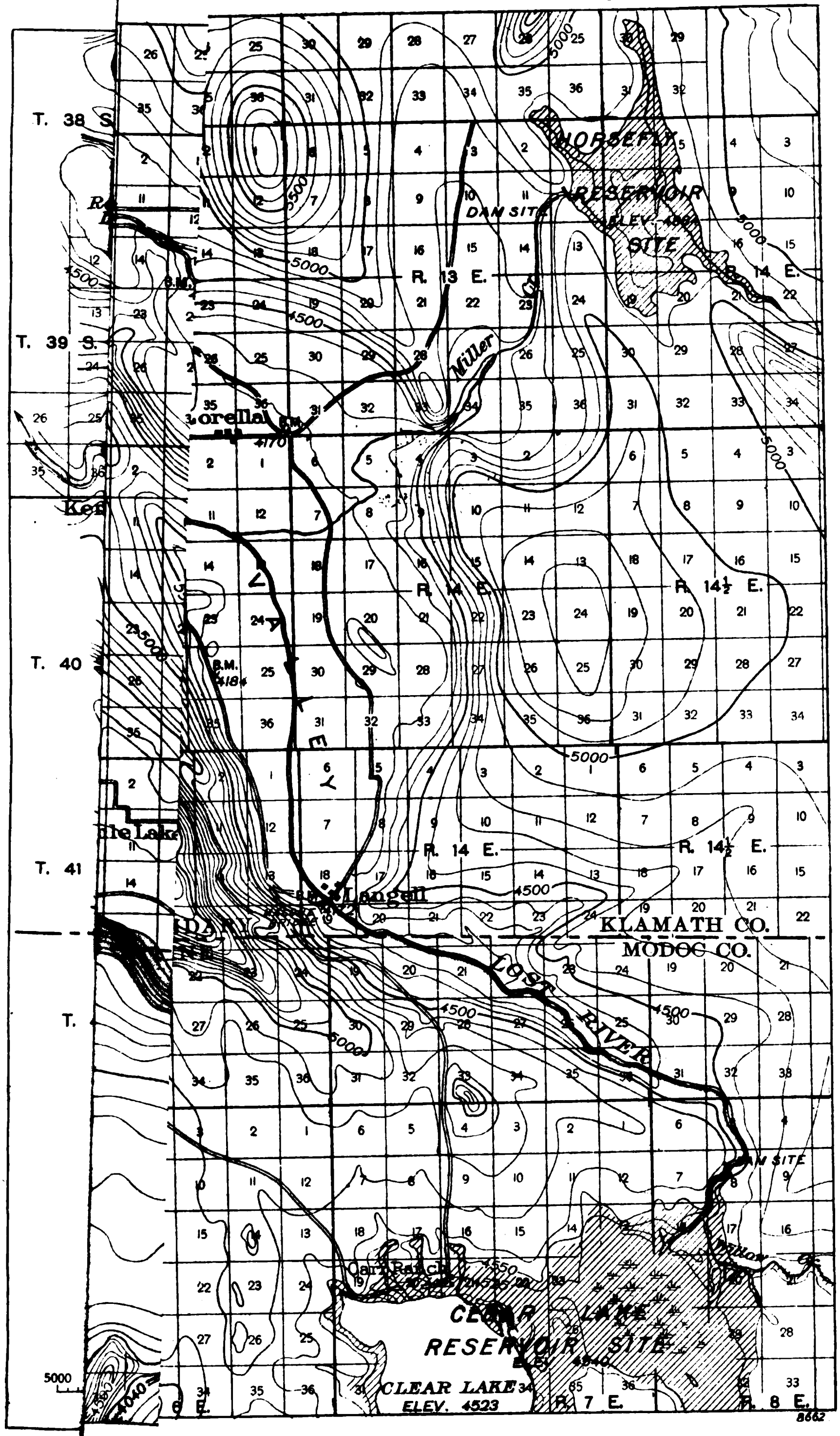
PLATE VIII



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